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A FLORISTIC STUDY OF THE SAVANNA VEGETATION OF THE STATE OF AMAPÁ, BRAZIL, AND SUGGESTIONS FOR ITS CONSERVATION[1]

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ABSTRACT - A total of 61 tree and large shrub and 69 smaller species were recorded in 11 surveys of savanna areas from the south to the north of the state of Amapá. Quantitative phytosociological data were collected for four areas. Almost all the important woody species with high IVI values are of widespread distribution and occur in the Central Brazilian cerrado vegetation. Two families of great importance in the tree flora of the cerrados, the Leguminosae and the Vochysiaceae, are very poorly represented in the Amapá savannas, the former by two and the latter by only one species. In common with other Amazonian savannas, those of Amapá are floristically depauperate when compared to the core area of Brazilian cerrado vegetation. Soil samples collected in most of the sites surveyed had low pH and mineral availability.

KEY WORDS: Cerrado, Phytosociology, Savanna, Amapá, Brazil.

RESUMO - Um total de 61 espécies de árvores e arbustos grandes e 69 espécies de menor porte foram registradas em 11 levantamentos conduzidos

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do sul ao norte das savanas do estado do Amapá. Quatro levantamentos incluíram coleta de dados fitossociológicos quantitativos. A grande maioria das espécies lenhosas com valores de IVI mais elevados apresentam ampla distribuição e ocorrem nos cerrados do Brasil Central. Leguminosae e Vochysiaceae, duas famílias de grande importância na flora arbórea dos cerrados do Brazil Central, são pouco representadas nas savanas do Amapá. A primeira por duas e a segunda por apenas uma espécie na área. As savannas do Amapá, como outras savanas amazônicas, são floristicamente pobres em comparação com a área core dos cerrados brasileiros. Amostras de solos coletadas para a maioria dos locais visitados apresentaram pH e nível de nutrientes baixos.

PALAVRAS-CHAVE: Cerrado, Fitossociologia, Savana, Amapá, Brasil.

INTRODUCTION

In addition to the 2 million km² of cerrado (tree savanna) that dominate the natural vegetation of Central Brazil, there are large disjunct patches of savanna across Amazonia. The Amazonian savannas are structurally similar to the cerrados, although they are often classified separately owing to the absence of certain characteristic cerrado species and their different soils and climate (Eiten 1978). Despite the growing number of published studies on these areas, much remains unclear as to their structure, species composition, and floristic links with other savanna areas, both within Brazil and in the adjoining countries of Venezuela, Colombia, Surinam and Guyana.

Amapá has 11,000 km² of isolated savanna limited to a long strip stretching in a NE direction along most of the state and a number of important studies on this vegetation have been undertaken (Magnanini 1952; Azevedo 1967; Ledoux 1968, 1969; Projeto... 1974; Ab'Sáber 1982). Azevedo (1967), for example, found a gradient of savanna formations in the state, from cerrado-type savannas to treeless campos and seasonal swamps dominated by tall grasses and sedges, with similar formations occuring on Marajó Island (Bastos 1984).

The present work is devoted to a floristic study of the savannas of the state of Amapá and seeks to describe their structure and composition and to investigate their links with other savanna areas.

DESCRIPTION OF THE STUDY AREA

Amapá is the most north-easterly state of Brazil and covers an area of 136,450 km². It is bounded to the NE by the Atlantic Ocean and SE by the Rio Amazonas, and shares its northernmost frontier with French Guiana. To the SW, the Rio Jari delimits its border with the state of Pará.

The climate is tropical and maritime with high temperatures all year round and is classified as Köppen's Amw' of the tropical rain climate (Eidt 1968). The mean annual temperature is 26°C, with the mean annual rainfall ranging between 2321 mm and 3250 mm. There is a short dry season of two to three months duration between August and October which is most pronounced in the southern half of the state (IRDA/IBGE 1966).

Leite et al.(1974) recognises three distinct ecological regions in Amapá. These are defined as closed forest (105,000 km²), savanna (11,000 km²) and coastal formations, consisting principally of mangrove, várzea (seasonally inundated forest) and flooded grasslands (20,000 km²). The vegetation pattern reflects the geology of the state which is underlain in its entirety by the ancient Guyanan shield, with Tertiary and Quaternary deposits present on its eastern coastal border (Formação Barreiras). The savanna soils, as defined by Peres et al. (1974), are principally dystrophic yellow latosols orthox (Sanches 1976).

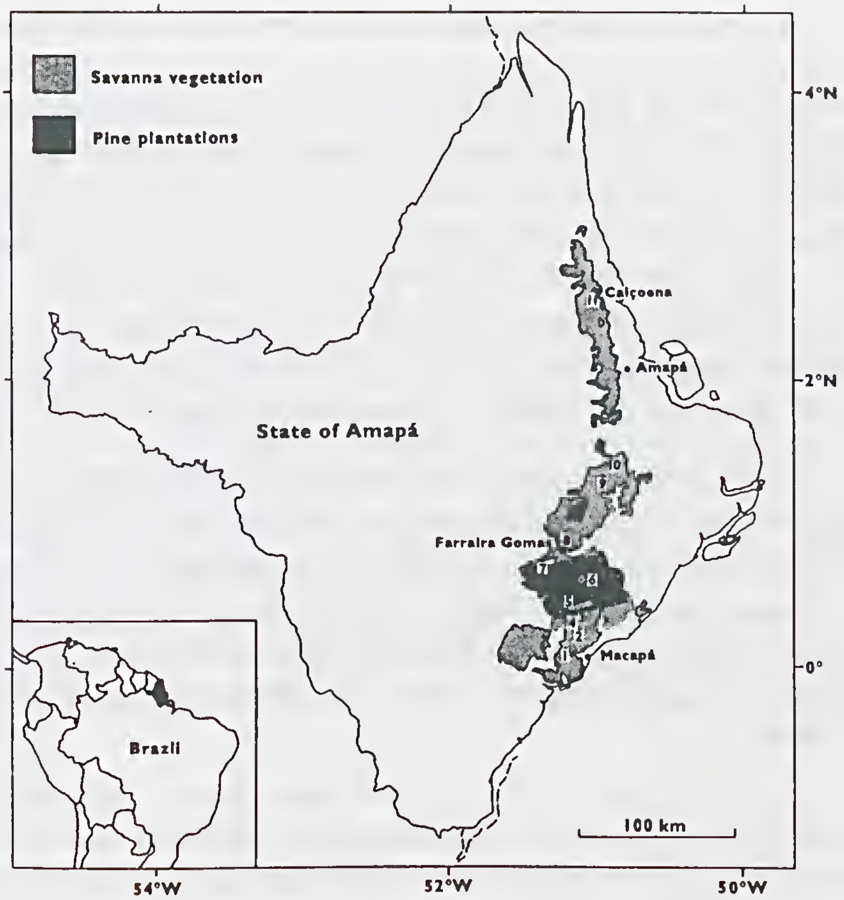
Until 15 years ago the savannas were relatively well-preserved, despite the long history of colonization of the state. However, in recent years urbanisation, agricultural expansion and especially the establishment of forestry plantations, mainly of *Pinus caribaea* (McDonald & Fernandes 1984), have rapidly reduced the area of unmodified savanna. We estimate from existing maps that at least 30% of the savanna area has been altered to date.

Between July 1993 and March 1994, we visited 11 areas of savanna in the localities listed below which cover a wide range of the latitudinal distribution of this vegetation within the state (Figure 1).

MATERIALS AND METHODS

Floristic surveys were made at all sites by general observation and collecting, special attention being given to the woody species. Voucher specimens are lodged in the herbaria of the Centro Zoobotânico of Macapá (HAMAB), the Instituto Nacional de Pesquisas da Amazônia (INPA), the University of Brasília, DF (UB), and the Royal Botanic Garden Edinburgh, Scotland (E). General observations were made at the sites of quantitative surveys, at random stops along the roads and occasionally near forest/savanna boundaries.

Quantitative data for the woody plant component were collected at four sites: 4, 6, 8 and 9. The Point-Centred Quarter method (PCQ), as described by Mueller-Dombois & Ellenberg (1974), was used where the average height of the woody vegetation was in excess of 2 m. Twenty points were used for each transect (sites 4 and 8). Quadrats of 20 m x 50 m were used when the vegetation was lower than 2 m or when its open nature made the PCQ method inappropriate (two quadrats for site 6 and three quadrats for site 9). Both methods were applied in areas at lest 200 m away from the nearest forest, to avoid inclusion of any forest species, and following the topography to avoid vegetation grandients.



(1) APA do Curiaú (Environmentally Protected Unit), 9 km N de Macapá (00°02'N, 51°03'W), (2) 27 km N of Macapá (00°14'N, 51°06'W); (3) EMBRAPA-CPAF station (The National Agricultural Research Agency, Centre for Agroforestry Research of Amapá), 45 km N of Macapá (00°25'N, 51°17'W); (4) Opposite the entrance to EMBRAPA-CPAF station, 45 km N of Macapá (00°25'N, 51°17'W); (5) Ministry of Defence area, 53 km N of Macapá (00°27'N, 51°05'W); (6) Gleba Pedreira-AMCEL (Amapá Celulose S.A.), 78 km N of Macapá (00°40'N, 51°45'W); (7) 113-114km N of Macapá (00°46'N, 51°18'W); (8) 4 km N of Ferreira Gomes bridge (00°54'N, 51°11'W); (9) 50 km S of Tartarugalzinho (01°09'N, 51°02'W); (10) 5 km S of Tartarugalzinho (01°40'N, 50°50'W); (11) 5 km S of Calçoene (02°28'N, 50°59'W).
Projeto... (1974) classified sites 1 to 10 as tree savannas (cerrado parque) and site 11 as isolated grassland (campo cerrado/cerrado parque).

Figure 1 - Distribution of the savanna vegetation of Amapá showing the 11 study sites and areas replaced by pine plantations.

In all surveys, species, height, and diameter at 1.3 m (breast height) above ground level were recorded for all individuals with a diameter ≥ 5 cm and ≥ 10 cm. Where trunks divided below 1.3 m the diameter of all branches at this height were recorded. The diameter of inclined trees was measured at 1.3 m from the base along the line of the trunk. The number of individuals, relative density, relative frequency, basal area (calculated either from single trunk or multiple branches), relative dominance and importance value index (IVI = Rel. dens. + Rel. dom. + Rel. freq.) were calculated for each species using the FITOPAC program, package version 2.0 (G. Shepherd, unpublished, University of Campinas, SP, Brazil).

In each of the study areas where quantitative data of vegetation were collected, between two and five randomly selected samples of soil were collected from 0-10 cm depth. A single soil sample was taken where only floristic surveys were undertaken. Chemical and granulometric analyses of these samples were carried out at EMBRAPA-CPAC (The National Agricultural Research Agency, Centre for Agricultural Research of the Cerrado).

Two multivariate analyses were performed in order to seek latitudinal patterns in the structure and distribution of the vegetation, and the soil properties. However, the conclusions from these analyses are of limited value since there was no replication of samples at each latitude.

The soil information of seven sites was analysed by Principal Component Analysis (PCA), using the correlation path in the CANOCO Program Version 3.1 (ter Braak 1988), with all data log-transformed to reduce the variance.

The floristic information (presence and absence of species) of all 11 study sites was analysed by TWINSPAN (a divisive hierarchical classification by Two-Way Indicator Species Analysis) using the package VESPAN II (Malloch, 1988). Species occurring only on the forest border were excluded from the analyses.

RESULTS

A list of all tree and large shrubs species recorded at the 11 survey localities is given in Table 1. The complete species list (including herbs and other low species) for all areas visited is presented in the Appendix. As anyone who has worked in savanna vegetation knows, it is often difficult to decide the correct growth-form category of a species, and therefore it is important to explain the criteria we have used. Our 'trees and large shrubs' include those shrubs which exceed 1 m in height and have long-lived woody aerial stems. Plants with short-lived woody shoots usually produced in a single flush of growth from a xylopodium (hemixyles, or renewable shrubs), e.g. many species of *Cassia* (*sens. lat.*), *Mimosa*, Malpighiaceae etc. are not included in this category. 'Smaller shrubs (including hemixyles) and herbs' are lumped together as a single category in the Appendix, while lianas and climbers, and parasites, are given distinct categories. Detailed phytosociological data are given in Tables 2-3 and synthesized in Table 4. The results of the soil analyses are shown in Table 5.

Table 1 - List of all tree and large shrub species occurring in the 11 survey sites (N=59). (s) present only as a small shrub (b) present only on the border with gallery forest.

	SITES										
SPECIES	1	2	3	4	5	6	7	8	9	10	11
Aegiphila cf. *cremata* Moldenke	x	-	-	-	-	-	-	-	-	-	-
Aegiphila cf. *parviflora* Moldenke	x	x	x	x	x	-	-	-	-	-	-
Anacardium occidentale L.	-	x	-	x	-	-	-	x	-	x	-
Anadenanthera peregrina Speg.	b	-	-	-	-	-	-	-	-	-	-
Annona paludosa Aubl.	s	x	x	s	s	s	x	x	-	s	-
Astronium fraxinifolium Schott.	-	-	b	-	-	-	-	-	-	-	-
Bactris sp.	-	-	-	-	-	-	-	-	-	-	x
Bowdichia virgilioides Kunth	x	x	b	x	-	-	-	-	-	-	-
Byrsonima coccolobifolia Kunth	x	x	x	x	x	x	x	x	x	-	-
Byrsonima cf. *crassa* Nied.	-	x	x	x	x	-	-	x	-	-	-
Byrsonima crassifolia (L.) Kunth	x	x	x	x	x	x	x	x	x	x	x
Casearia grandiflora Cambess.	-	-	-	x	x	x	x	x	-	-	-

	SITES										
SPECIES	1	2	3	4	5	6	7	8	9	10	11
Casearia sylvestris Sw.	x	x	x	s	-	x	-	x	-	-	-
Chrysobalanus icaco L.	-	-	-	-	-	-	-	-	-	-	x
Clusia sp.	-	-	-	-	-	-	-	-	-	-	x
Coccoloba sp.	-	-	b	-	-	-	-	-	-	-	x
Connarus perottetii (DC.) Planch. var. *angustifolium* Radlk.	x	-	-	s	-	-	-	-	-	-	-
Cupania diphylla Vahl	-	-	-	-	-	x	-	-	-	-	-
Curatella americana L.	x	x	x	x	x	x	x	x	x	-	-
Duroia duckei Huber	-	-	-	-	-	-	-	-	-	-	x
Erythroxylum suberosum A. St. Hil.	s	s	s	-	-	-	-	-	-	-	-
Guettarda sp.	-	-	b	-	-	-	-	-	-	-	-
Hancornia speciosa Nees & Mart.	x	-	-	-	-	-	-	x	-	-	-
Himatanthus articulatus (Vahl) R. E. Woodson	x	x	x	x	x	x	x	x	x	x	x
Hirtella ciliata Mart. ex Zucc.	x	-	-	x	-	x	-	-	-	x	x
Hirtella racemosa Lam. *var. hexandra* (Willd. ex R. & S.)	-	-	-	-	-	-	x	x	-	x	x
Humiria balsamifera (Aubl.) St. Hil.	-	-	-	-	-	-	-	-	-	x	x
Hymenolobium cf. *petraeum* Ducke	b	-	-	-	-	-	-	-	-	-	-
Inga marginata Willd.	-	-	b	-	-	-	-	-	-	-	-
Jacaranda copaia (Aubl.) D. Don	-	-	-	-	-	x	-	-	-	-	-
Lacistema aggregatum (Berg) Rusby	-	-	s	-	-	-	x	-	-	-	-
Lafoensia cf. *pacari* A. St. Hil.	-	-	-	-	-	-	-	-	x	-	-
Licania longistyla (Hook. f.) Fritsch	-	-	-	-	-	-	x	-	-	x	-
Luehea sp.	-	-	b	-	-	-	-	-	-	-	-
Maprounea guianensis Aubl.	s	-	-	-	-	-	-	x	-	-	-
Mezilaurus lindaviana Schwacke & Mez	b	-	b	-	-	-	-	-	-	-	-
Myrcia cuprea Kiaersk.	x	-	-	x	-	-	x	-	-	-	-
Myrcia cf. *fallax* (Rich.) DC.	-	-	-	-	-	x	-	-	-	-	-
Myrcia obtusa (Schauer) Berg	-	-	-	-	-	x	-	-	-	-	-
Ouratea castaneaefolia Engl.	-	-	-	-	-	-	-	-	-	-	x
Ouratea hexasperma (St. Hil.) Benth.	x	x	x	x	-	x	x	x	x	x	-
Palicourea rigida Kunth	s	s	x	s	-	x	s	x	x	s	-
Plathymenia reticulata Benth.	-	-	b	-	-	-	-	-	-	-	-
Psidium sp.	-	-	x	x	-	-	-	-	-	-	-
Rauvolfia pentaphylla Ducke	x	-	-	-	-	x	x	-	-	-	-

	SITES										
SPECIES	1	2	3	4	5	6	7	8	9	10	11
Roupala montana Aubl.	x	-	b	x	-	x	x	-	-	-	-
Salvertia convallariodora St. Hil.	x	x	x	x	x	x	-	-	-	-	-
Sapium longifolium Boj.	x	-	-	-	-	-	-	-	-	-	-
Simarouba amara Aubl.	x	x	b	-	-	x	-	-	-	-	-
Siparuna guianensis Aubl.	-	-	-	-	-	-	s	-	-	-	-
Symplocos guianensis Guerke	-	-	-	-	-	-	-	x	-	-	-
Tabebuia aurea Benth. & Hook.	x	-	b	-	-	x	-	-	-	-	-
Tabebuia serratifolia Rolfe A. O. F.	-	-	b	-	-	-	-	-	-	-	-
Tocoyena formosa (C. & S.) Schum.	x	-	-	x	-	x	x	x	-	-	-
Trattinickia rhoifolia Willd.	b	-	-	-	-	-	-	x	-	x	-
Vismia guianensis (Aubl.) Choisy	-	-	x	x	-	x	-	-	-	-	-
Vitex sp.	x	-	b	-	-	-	-	x	-	-	-
Xylopia aromatica Lam.	-	-	-	-	-	x	-	-	-	-	-
TOTAL	29	15	28	20	9	22	17	18	7	11	11

Table 2 - Phytosociological data for the two savanna areas surveyed with 20 point PCQ transects (≥ 5cm dbh).

	Opposite Embrapa station (site 4)						4 km N of Ferreira Gomes (site 8)					
SPECIES	n	Total ba	Rel. dens.	Rel. dom.	Rel. freq.	IVI	n	Total ba	Rel. dens.	Rel. dom.	Rel. freq.	IVI
Byrsonima crassifolia	28	0,36	35,00	32,64	29,08	96,73	34	0,58	42,50	41,28	31,25	108,05
Himatanthus articulatus	11	0,21	13,75	18,94	14,55	47,23	26	0,78	32,50	30,88	35,42	105,58
Ouratea hexasperma	15	0,23	18,75	20,38	21,80	60,94	1	0,05	1,25	2,67	2,08	6,07
Byrsonima coccolobifolia	12	0,13	15,00	11,91	14,55	41,46	11	0,20	13,75	10,46	16,67	40,62
Roupala montana	3	0,03	3,75	2,67	3,64	10,06	0	0	0	0	0	0
Curatella americana	3	0,04	2,50	3,03	3,64	9,17	2	0,02	2,50	1,39	4,17	8,10
Hirtella ciliata	3	0,06	3,75	5,30	3,64	12,68	0	0	0	0	0	0
Tocoyena formosa	3	0,02	3,75	1,90	3,64	9,29	0	0	0	0	0	0
Bowdichia virgilioides	2	0,02	2,50	1,77	3,64	7,91	0	0	0	0	0	0
Anacardium occidentale	1	0,02	1,25	1,46	1,82	4,53	5	0,25	6,25	13,02	8,33	27,94
Maprounea guianensis	0	0	0	0	0	0	1	0,01	1,25	0,30	2,08	3,64
Totals	81	1,12	100	100	100	300	80	1,89	100	100	100	300

n = number of individuals; ba = basal area (m^2/ha); Rel.dens. = relative density; Rel.dom. = relative dominance; Rel.freq. = relative frequency; IVI = importance value index.

Table 3 - Phytosociological data for the two savanna areas surveyed with 50 x 20m quadrats (≥ 5cm dbh) (two quadrats for site 6 and three for site 9).

	50km S of Tartarugalzinho (site 9)						Gleba Pedreira da AMCEL (site 6)					
SPECIES	n	Total ba	Rel. dens.	Rel. dom.	Rel. freq.	IVI	n	Total ba	Rel. dens.	Rel. dom.	Rel. freq.	IVI
Ouratea hexasperma	15	0,32	50,00	40,79	27,28	118,05	5	0,17	31,25	27,99	28,57	87,81
Byrsonima crassifolia	8	0,16	26,67	19,97	27,27	73,92	7	0,17	43,75	27,92	28,57	100,24
Byrsonima coccolobifolia	4	0,17	13,33	21,41	18,18	52,93	3	0,18	18,75	29,51	28,57	76,83
Himatanthus articulatus	1	0,01	3,33	6,60	9,09	19,02	1	0,09	6,25	14,58	14,29	35,12
Curatella americana	1	0,08	3,33	10,30	9,09	22,73	0	0	0	0	0	0
Palicourea rigida	1	0,01	3,33	0,93	9,09	13,35	0	0	0	0	0	0
Totals	30	0,75	100	100	100	300	16	0,61	100	100	100	300

n = number of individuals; ba = basal area (m^2/ha); Rel.dens. = relative density; Rel.dom. = relative dominance; Rel.freq. = relative frequency; IVI = importance value index.

Table 4 - Phytosociological information of the four savannas surveyed (≥ 5cm dbh). Area = area surveyed; n = number of individuals; ns = number of species; nf = number of families; ba = basal area per hectare; ah = average height.

Site	Site no.	Method	no. of samples	Area (ha)	n	ns	nf	ba (m^2/ha)	ah (m)	Density/ ha
Opposite EMBRAPA	4	PCQ	20	0,38	80	10	9	1,12	3,95	213
4 km N of Ferreira Gomes	8	PCQ	20	1,29	80	7	6	1,89	4,50	62
Gleba Pedreira-AMCEL	6	Q	2	0,20	16	4	3	0,61	3,11	80
50 km S of Tartarugalzinho	9	Q	3	0,30	30	6	5	0,75	3,03	100

Table 5 - Soil pH, exchangeable aluminium (Al), calcium (Ca), magnesium (Mg), phosphorus (P) and potassium (K), organic matter (OM), coarse sand (CS), fine sand (FS) and particle size composition for 0-10 cm deep soil samples for seven areas. Values are means of the sample numbers (N) indicated.

Site	site no.	pH H_2O	OM (%)	P (ug g^{-1})	K	Ca (meq/100g^{-1})	Mg	Al	Clay (%)	CS	FS	Silt
27 km N of Macapá (N = 3)	2	5,4	1,37	2,7	6,7	0,06	0,11	0,99	44	26	26	4,0
Inside EMBRAPA (N = 1)	3	4,9	1,56	2,7	3,0	0,18	0,10	0,84	32	15	52	1,0
Opposite EMBRAPA (N = 5)	4	4,9	0,67	2,8	1,2	0,10	0,05	0,37	14	8	77	0,8
Gleba Pedreira-AMCEL (N = 2)	6	4,7	1,69	2,5	3,0	0,10	0,05	0,85	41	32	27	1,0
113-114 km N of Amapá (N = 1)	7	4,9	1,51	2,6	2,0	0,15	0,05	0,78	33	19	47	1,0
4 km N of Ferreira Gomes (N = 6)	8	4,8	0,99	3,0	5,8	0,11	0,06	0,45	19	37	43	0,5
50 km S of Tartarugalzinho (N = 3)	9	4,8	2,19	2,9	7,0	0,17	0,08	0,68	33	26	40	1,3
5 km S of Calçoene (N = 1)	11	4,5	0,35	2,4	0,0	0,07	0,04	0,08	25	1	74	0,0

SciELO

A total of 130 species were observed of which 61 were trees or large shrubs. However, during the quantitative surveys, only 12 species were recorded with a diameter at breast height (dbh) of ≥ 5 cm and no single area surveyed had more than 10 woody species. It was rare for the larger woody plants to achieve heights in excess of 4 m, or for the occasional emergents (usually *Byrsonima crassifolia, Himatanthus articulatus* and, occasionally, *Roupala montana*) to exceed 6m. All areas were characterised by their dwarfed stature, which was of a lower and more open structure compared to the cerrado sensu stricto of Central Brazil.

The commonest species observed were *Byrsonima crassifolia* and *Himatanthus articulatus* which occurred at every study site. All areas showed a few species with similar high IVI ranks, principally *Byrsonima crassifolia*, *Himatanthus articulatus*, *Ouratea hexasperma* and *Byrsonima coccolobifolia*, *Curatella americana*, *Tocoyena formosa*, *Salvertia convallariodora*, *Roupala montana*, *Byrsonima crassa*, *Aegiphila* cf. *parviflora*, *Anacardium occidentale* and *Rauwolfia pentaphylla* were present in lower numbers. The analysis of the measurements of trees with dbh ≥ 10 cm showed no change in the order of IVI values, except for an added record of *Trattinickia rhoifolia* at site 8, therefore these results are not presented. None of the sites had species exceptional for savannas, except for the two northernmost areas where *Humiria balsamifera*, *Chrysobalanus icaco* and a *Bactris* sp. were recorded.

The majority of areas had under 100 individuals per hectare, but an exception (site 4) had more than 200 individuals (Table 4). A latitudinal gradient in physiognomy was observed, with the northernmost sites tending to have a more strongly developed hebaceous layer and fewer trees and shrubs.

A visual estimate of the ground cover of the savanna areas visited ranged from 40% to 100% and tended to be dominated by the grass *Trachypogon plumosus* and the sedge *Bulbostylis spadicea*, with *Scleria cyperina*, *Rhynchospora barbata* and *Paspalum carinatum* also common.

The TWINSPAN classification of the floristic information indicates a latitudinal pattern existing within the savanna, with all the northern sites (sites 7 to 11) separated from the southern sites on the basis of their component species (Figure 2). Site 11 is classified distinctly from all other sites at the first division due to a high percentage of its flora (*Bactris* sp. *Chrysobalanus icaco, Clusia* sp. *Duroia duckei* and *Ouratea castanaefolia*) only noted at this site. Species identified by TWINSPAN as being strongly preferencial to the southern areas of savanna include *Bowdichia virgilioides*, *Aegiphila* cf. *parviflora* and *Salvertia convallariodora*. The authors also noted apparent distribution gradients of some other principal species such as *Byrsonima verbascifolia* which dramatically increased in abundance in the north of the state. Some species, *Byrsonima crassifolia, B. cocolobifolia, Himatanthus articulatus, Ouratea hexasperma, Annona paludosa* and *Curatella americana* were widely distributed.

The soils of all areas ranged from sandy to clayey, and were strongly to medium acid (pH ≤ 5.5). They were poor in nutrients, and low in organic matter, with the soil surface frequently indurated by iron concretions (Table 5).

The ordination of the areas based on soil information shows a pattern which is highly correlated to vegetation physiognomy (Figure 2). The eigenvalues for the four PCA axes were 0.43, 0.167, 0.137 and 0.086. The cumulative percentage variance for the axes were, respectively, 43.4%, 60.1%, 73.9% and 82.5%. The first axis was positively correlated with fine sand (FS), and negatively correlated with coarse sand (CS), silt and clay, whilst axis II was positively correlated to pH and magnesium (Mg) and negatively correlated to phosphorus (P) and calcium (Ca). The study sites with average vegetation height (sites 6 and 9) were negatively correlated with axis I, and contained high levels of clay (> 30%). Sites with higher height averages (sites 3, 4, 7 and 8) were positively correlated with axis I, and had lower clay levels (between 15-20% for site 4 and 8, and 30% for sites 3 and 7). However, site 2, also of higher vegetation

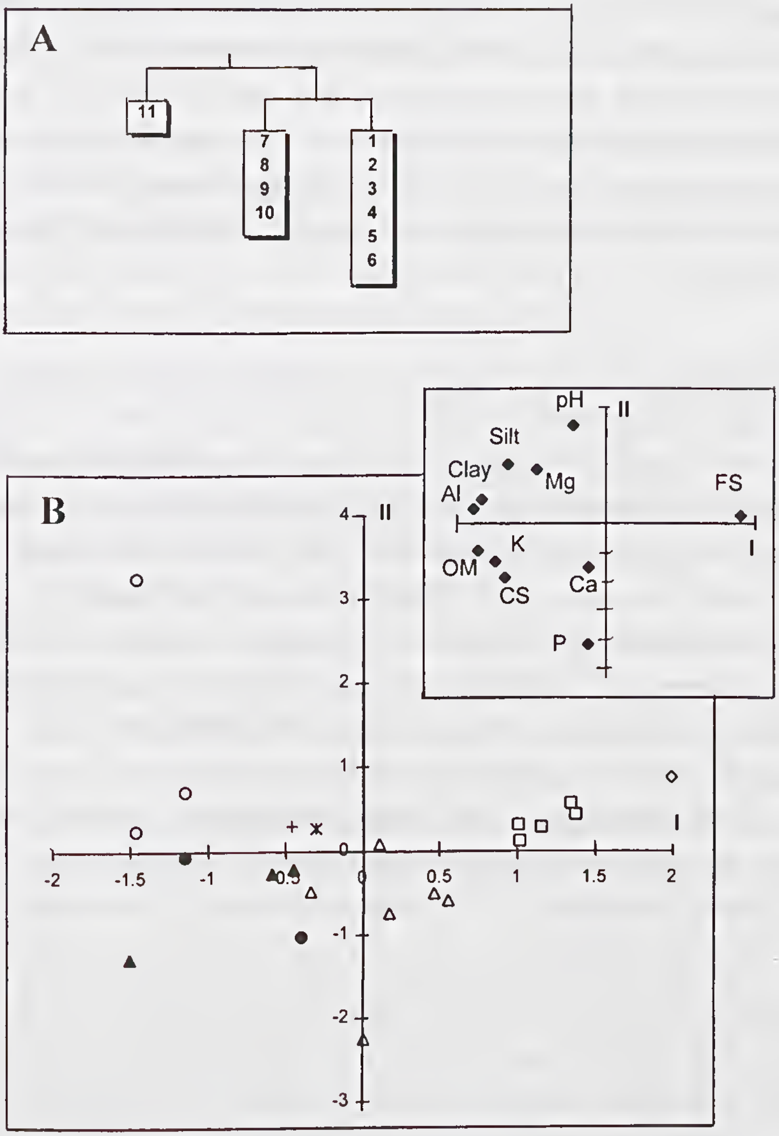


Figure 2 - (A) TWINSPAN hierarchical classification of the 11 study sites after two levels of division. (B) PCA of 22 (0-10 cm) soil samples from eight study sites: (o) site 2, (□) site 4, (Δ) site 8, (◇) site 11 (+), site 3, (∗) site 7, (●) site 6, (▲) site 9. Open symbols = vegetation height about 3 m, closed symbols = vegetation height above 4m, others = vegetation near forest borders.

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height showed a negative correlation with Axis I and had high clay values ($\geq 40\%$). Only one site, with a high vegetation height (site 11), showed an extremely high negative correlation with axis I. The soils of this site contained only fine sand (74%) with a clay composition up to 25%, and contained species characteristic of a waterlogged habitat (*Bactris* sp., the acaulescent form of *Byrsonima verbascifolia* and several species of *Utricularia*).

DISCUSSION

The savanna vegetation of Amapá is poor in species compared to the cerrados of Central Brazil. It is not uncommon for cerrado areas to harbour more than 100 tree and large shrub species (Ratter 1980; Gibbs et al. 1983; Pott et al. 1986; Oliveira-Filho & Martins 1991; Felfili et al.1993), while the present study recorded only 61, despite surveying 11 savanna areas covering two degrees of latitude. Previous floristic studies conducted in the state of Amapá (Azevedo 1967; Leite *et al*. 1974) recorded a total of 14 species of trees. Only two species from these studies, an unidentified member of Burseraceae (breu branco, probably *Protium* sp. or *Tetragastris unifoliolata* (Engl.) Quatr.) (Azevedo 1967) and a species of *Qualea* (Leite *et al*. 1974) were not found in this study.

The relative species poorness of the Amazonian savannas is well documented. Milliken & Ratter (1989) recorded 31 tree and large shrub species in a *Curatella americana*/*Byrsonima* crassifolia campo on Maracá island in Roraima, whilst the current authors have recorded 46 such species in the savannas near Alter do Chão, Pará (of which Miranda (1993) found 19 species within a 3.5 ha area). Other accounts of relatively depauperate floras in the savannas of Brazilian Amazonia and also those of Guyana, Surinam, Venezuela and Colombia have been published by a number of authors (Egler 1960; Takeuchi 1960; Blydenstein 1967;

Goodland 1966; van Donselaar 1965; Bastos 1984; Gottsberger & Morawetz 1986). Although the majority of these sites are species poor, relatively diverse floras have also been documented for some isolated savanna areas in Amazonia: for instance, Janssen (1986) listed 67 species of trees for the savannas near Humaitá, in the state of Amazonas. The reasons for the paucity of species in most of these areas remains unclear, although the presence of a perched high water-table has been proposed as a contributing factor (Sarmiento & Monasterio 1975).

All of the species dominating the woody component of the Amapá savannas are common in the Brazilian cerrados. *Curatella americana* and *Byrsonima crassifolia* are widespread in South and Central American savannas and their ability to withstand periodic waterlogging, enabling them to colonise a wide variety of sites, is well-known (see, for instance, Foldats & Rutkis 1975; Ratter 1992). The savannas of Amapá are dominated by only a few species, and this appears to be a common feature of many of the Amazonian savannas. Although *C. americana* and *B. crassifolia* are usually among the dominant species in most Amazonian savannas, there is much variation between sites in the other principal species. In Amapá, *Himatanthus articulatus, Ouratea hexasperma* and *Byrsonima coccolobifolia* are the most common, followed by *B. crassifolia* and *C. americana*. However, Gottsberger & Morawetz (1986) noted *Physocalymma scaberrimum* (a species not recorded in Amapá) as being one of the dominants in Humaitá, while Takeuchi (1960) reported that *Cassia flexuosa* (also unrecorded in Amapá) is sometimes found as a monodominant in the savannas of Roraima state. This variation in the principal species probably has as much to do with chance as with ecological preferences. The lack of both floristic and ecological information limits further discussion.

The only unusual woody species recorded were *Chrysobalanus icaco* (also recorded by Azevedo (1967)) and *Humiria balsamifera*, both recorded north of the city of Amapá. The occurrence of these species was associated with the presence of well-drained sandy soils, and our samples collected from the two white sand sites (10 and 11) were very different in texture from all the others (due to the absence of coarse sand) and showed the lowest levels of calcium, magnesium, phosphorus and organic matter. In fact, white sand woodlands are a typical habitat of *H. balsamifera* across northern South America (Granville 1982; van Donselaar 1965). Milliken & Ratter (1989) recorded it associated with *Curatella americana* and *Byrsonima crassifolia* on Maracá Island, Roraima, and Bastos (1984) on Marajó Island. *Chrysobalanus icaco* is very characterisic of the low savanna scrub which occurs behind the strand line of the Central American (Furley & Ratter 1992) and northern South American coast (Huber 1898) on Marajó Island and this habitat resembles that of the Amapá savannas.

In contrast to the Central Brazilian cerrados, only one species of the Vochysiacéae (*Salvertia convallariodora*) and two of the Leguminosae (*Anadenanthera peregrina* and *Bowdichia virgilioides*) were found. These are two of the most important woody families of the cerrado in terms of both vegetation cover and number of species. *Qualea grandiflora*, *Q. multiflora* and *Q. parviflora* of the Vochysiaceae are amongst the most widespread cerrado tree species (Ratter & Dargie 1992) but there are no substantiated records from the savannas of Amapá, although Leite et al. (1974) refer to the presence of a '*Qualea*'. *Q. parviflora* is not found in savannas further north than Humaitá, Amazonas state (Janssen 1986), whilst *Q. grandiflora* is found as far north as Monte Alegre, just north of the Amazon river (Andrade-Lima 1958). There are no records of either of these species from the savannas of Roraima state. *Salvertia convallariodora* shows an interesting pattern of distribution in Amapá where it is abundant in the south and absent in the north. The presence of great numbers of apparently young or dwarf plants was noted in areas where few trees of this species occurred and perhaps a process of northward colonization is occurring. Amapá represents the northernmost Brazilian distribution of *S. convallariodora*, although it has been recorded as far north as Surinam (Kubitzki 1983). Of the two species of Leguminosae, *Anadenanthera peregrina* was only found on the savanna border with gallery forest, while *Bowdichia virgilioides* shows the same distribution pattern as *S. convallariodora*, being present in the south and absent in the north. This species is abundant from the cerrados of São Paulo in the south to the savannas of Venezuela in the north.

The tree savannas we studied in Amapá were of small stature, with low and sparse trees compared to those of the majority of cerrado vegetation in Central Brazil. This is in common with many Amazonian savannas, but there are exceptions: the savannas of Alter do Chão, Pará, for example, have a dense tall woody component and show a classic cerrado form. Many factors might be involved in the prevalence of dwarf savannas in Amazonia (e.g. soil nutrients and water-table depths) and this would provide an interesting field for further investigation.

Some of the most common ground cover species in Amapá, such as species of *Trachypogon*, *Bulbostylis* and *Paspalum* are also the principal species in other Amazonian savannas (Egler 1960, Takeuchi 1960, Sanaiotti & Magnusson 1995).

The soils at all sites were sandy to clayey and strongly to medium acid, with low levels of silt (≤ 4%). Similar soil properties were found by Souza *et al*. (1992) and Peres *et al*. (1974), although in both cases greater levels of silt were recorded (≥ 10%).

Currently the only conservation unit in Amapá that includes the savanna ecosystem is the APA do Curiaú in the south of the state. This includes less than 2% of the total savanna area of the state, and to ensure adequate protection of the savanna vegetation of Amapá, more effective conservation units need to be established. These should take into account the latitudinal gradient described in this study. From our studies, we have suggested to the Amapá local Government Environmental Department (CEMA) the following five savanna areas that could provide the focus of any future conservation initiatives within the state:

1) Área do Exército (Ministry of Defence area), 53 km N of Macapá
2) Gleba Pedreira - AMCEL, 78 km N of Macapá
3) Between 40-48 km north of Macapá on the BR 156
4) Between the towns of Amapá and Calçoene
5) 10 km S of Tartarugalzinho

The criteria used in the choice of these sites were degree of naturalness and representation of the range of savanna vegetation types to be found in the state. Our investigations are preliminary, but provide a basis for further floristic studies aimed at the selection of further conservation areas.

As well the floristic aspect, fauna and habitat use must be considered when suggesting conservation areas. Since the Central Brazilian savannas are known to support large numbers of migratory birds (Antas 1983), one of us (T.M.S.) recorded non-resident species of birds for all sites visited as a subsidiary to the main vegetation study. Three migratory species were observed throughout the state from north to south, including the rare *Piranga rubra*. Also observed were *Tyrannus savana* and, in the várzea, *Leistes militaris*.

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APPENDIX

Appendix. List of all species of tree, shrubs and herbs observed in the 11 study areas. *Rhabdodendron amazonicum* and *Virola sebifera* were only recorded outside the study areas. (w) trees and large shrubs; (h) small shrubs and herbs; (p) parasite; (l) liana or herbaceous climber.

Aegiphila cf. *cremata* Moldenke	w
Aegiphila cf. *parviflora* Moldenke	w
Aegiphila cf. *lhotzkyana* Cham.	w
Alibertia elliptica (Cham.) K. Schum.	h
Amasonia campestris (Aubl.) Moldenke	h
Anacardium occidentale L.	w
Anadenanthera peregrina Benth.	w
Annona paludosa Aubl.	w
Aristida sp.	h
Astronium fraxinifolium Schott.	w
Bactris sp.	w
Borreria sp.	h
Bowdichia virgilioides Kunth	w
Buchnera palustris Spreng.	h
Bulbostylis spadicea Kunth	h
Byrsonima coccolobifolia Kunth	w
Byrsonima cf. *crassa* Nied.	w
Byrsonima crassifolia (L.) Kunth	w
Byrsonima verbascifolia Rich. ex A. Juss.	h
Casearia grandiflora Cambess.	w
Casearia sylvestris Sw.	w
Cassytha sp.	p
Chamaecrista desvauxii (Collad.) Killip	h
Chamaecrista diphylla Greene	h
Chamaecrista ramosa (Vogel) H. S. Irwin & R. C. Barneby	h

Chrysobalanus icaco L.	w
Clidemia sericea D. Don	h
Clusia sp.	w
Coccoloba sp.	w
Cochlospermum regium (Schrank) Pilg.	h
Comolia lytrarioides (Steud.) Naud.	h
Connarus perottetii (DC.) Planch. var. angustifolium Radlk.	w
Cordia multispicata Cham.	h
Coutoubea sp.	h
Cupania diphylla Vahl	w
Curatella americana L.	w
Curtia tenuifolia (Aubl.) Knobl.	h
Davilla rugosa Poir.	l
Declieuxia fruticosa (Willd. ex. R. & S.) O. Ktze.	h
Derris floribunda (Benth.) Ducke	l
Desmodium barbatum Benth. & Oerst.	h
Dioclea sp.	l
Diodia sp.	h
Doliocarpus cf. *brevipedicellatus* Garcke	l
Duroia duckei Huber	w
Eriosema sp.	h
Erythroxylum suberosum A. St. Hil.	w
Eugenia biflora DC.	h
Eugenia punicaefolia DC.	h
Galactia jussiaena Kunth	h
Guettarda sp.	w
Habenaria sp.	h
Hancornia speciosa Nees & Mart.	w
Heliconia psittacorum L.f.	h
Himatanthus articulatus (Vahl) R. E. Woodson	w
Hirtella ciliata Mart. ex Zucc.	w

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Hirtella racemosa Lam. var. *hexandra* (Willd. ex R. & S.)	w
Humiria balsamifera (Aubl.) A. St. Hil.	w
Hypolytrum cf. pulchrum (Rudge) Pffef.	h
Hypolytrum sp.	h
Hymenolobium cf. *petraeum* Ducke	w
Ichthyothere terminalis (Spreng.) Malme	h
Inga marginata Willd.	w
Irlbachia caerulescens (Aubl.) Griseb.	h
Jacaranda copaia (Aubl.) D. Don	w
Lacistema aggregatum (Berg) Rusby	w
Lafoensia cf. *pacari* A. St. Hil.	w
Licania longistyla (Hook. f.) Fritsch	w
Luehea sp.	w
Macroptilium lathyroides (L.) Urban	h
Manihot sp.	h
Maprounea guianensis Aubl.	w
Merremia aturensis Hallier f.	h
Mezilaurus lindaviana Schwacke & Mez	w
Miconia alata DC.	h
Miconia albicans (Sw.) Triana	h
Miconia ciliata Benth.	h
Miconia rufescens (Aubl.) DC.	h
Moutabea sp.	h
Myrcia cuprea Kiaersk.	w
Myrcia fallax (Rich.) DC.	w
Myrcia sylvatica DC.	h
Myrcia obtusa (Schauer) Berg	w
Ouratea castaneaefolia Engl.	w
Ouratea hexasperma (A. St. Hil.) Benth.	w
Pagamea guianensis Aubl.	h
Palicourea rigida Kunth	w

Paspalum carinatum Fluegge	h
Perama hirsuta Aubl.	h
Plathymenia reticulata Benth.	w
Polygala apressa Benth.	h
Polygala variabilis Kunth	h
Polygala thimoutou Aubl.	h
Psidium sp.	w
Psychotria barbiflora DC.	h
Psychotria sp.	h
Rauvolfia pentaphylla Ducke	w
Rhabdodendron amazonicum (Spr. ex. Benth.) Hub.	w
Rhynchospora barbata (Vahl) Kunth	h
Roupala montana Aubl.	w
Rourea sp.	h
Salvertia convallariodora A. St. Hil.	w
Sapium longifolium Boj.	w
Sauvagesia erecta L.	h
Scleria cyperina Kunth	h
Sebastiania sp.	h
Simarouba amara Aubl.	w
Sipanea pratensis Aubl.	h
Siparuna guianensis Aubl.	w
Sisyrinchium incurvatum Gardn.	h
Stylosanthes guianensis Sw.	h
Symplocos guianensis Guerke	w
Tabebuia aurea Benth. & Hook.	w
Tabebuia serratifolia Rolfe A. O. F	w
Tabernaemontana flavicans (R.& S.) Miers	h
Ternstroemia cf. *delicatula* Choisy	h
Tibouchina aspera Aubl.	h
Tocoyena formosa (C.& S.) Schum.	w

Trachypogon plumosus Nees	h
Trattinickia rhoifolia Willd.	w
Turnera brasiliensis Willd. ex Schult.	h
Turnera ulmifolia L.	h
Turnera sp.	h
Utricularia simulans Pilger	h
Utricularia spp	h
Virola sebifera Vahl	w
Vismia cayennensis (Aubl.) Choisy	h
Vismia guianensis (Aubl.) Choisy	w
Vitex sp.	w
Xylopia aromatica Lam.	w
Xyris sp.	h